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A simulation study of community-based falls prevention for older adults in Singapore: current reality, scenario analysis and ways forward

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Abstract

Background: Falls among older adults are a leading cause of injury and mortality in Singapore, yet a coordinated national prevention strategy remains lacking. This study aims to examine how Singapore can implement a national falls prevention strategy through an *in-silico* pre-implementation evaluation.

Methods: A system dynamics model was developed to model the current falls prevention landscape, identify system bottlenecks, and assess the impact of different policy scenarios over 30 years (2010–2040). The model incorporated demand and supply dynamics, including population dynamics, screening and intervention capacity, and uptake of interventions. Five policy scenarios were conducted, which included increasing uptake screening and intervention services, expanding screening capacity, implementing high-quality prevention programmes, and a combination of scenarios. Sensitivity analyses were conducted to assess model robustness.

Results: In the business-as-usual scenario, the number of fallers in Singapore is projected to triple by 2040. Some strategies, such as increasing service uptake, had minimal impact due to system bottlenecks. The most effective strategy was a combination package that integrated early screening, prioritizing high-risk individuals, and expanded programme capacity, that reduced total number of older adult fallers by up to 14% by 2040 compared to business-as-usual. Findings demonstrate the need for a coordinated, system-wide approach to falls prevention.

Discussion and Conclusion: Simply expanding community-based services is insufficient. The combination of targeted screening, structured referral pathways, and evidence-based intervention programmes, while accounting for system bottlenecks, is critical to ensuring older adults at high risk of falls receive care. This study highlights the essential need to address the burden of falls among older adults in Singapore and identifies potential strategies that may be implemented to do so.

Introduction

Falls among older adults are a result of interrelating risk factors that result in adverse consequences, including injury, disability, significant psychological burden and even death [1, 2]. Falls are complex: for instance, an older adult may transition from being healthy to developing osteoporosis and sarcopenia, which, when complicated by other risk factors such as gait instability and cognitive impairment, increases their likelihood of falling and sustaining a fragility fracture [3-6]. Older adults are especially at risk of serious fall-related injuries requiring hospitalisation and rehabilitation, among which hip fractures are associated with the highest rates of morbidity, mortality and economic burden [7, 8].

In Singapore, 85% of all geriatric trauma cases presented to the emergency department are due to a fall [9], and account for 40% of injury-related deaths among older adults [10]. While certain countries have established some national strategies and guidelines to prevent falls [11, 12], the implementation of nationwide falls prevention strategies in Singapore is in its infancy. Moreover, studies have indicated significant fragmentation of care in the Singapore healthcare system [13, 14]. For example, referrals into programmes occur in an *ad hoc* manner, which may lead to inconsistencies in access to preventive care [15, 16]. Hence, in a rapidly ageing country like Singapore, it is essential to consider an effective and proactive nationwide strategy to prevent falls.

The prevention of falls requires the implementation of effective falls prevention programmes. Multi-component falls prevention interventions comprise of at least two different types of interventions (e.g. exercise and medication review) [17]. While the evidence of such falls prevention programmes have been established, as noted, it is limited in scale in Singapore. In Singapore, most community-based programmes are group-based exercise programmes. While group-based exercise programmes may be useful in enhancing strength and balance among older adults, such programmes tend to cater broadly to older adults and are not prescriptive for individuals at high falls risk.

Given the etiologies of falls and the need for multi-specialty and multi-system approaches to prevention, this presents a complex and dynamic problem that requires coordinated solutions. Current studies evaluating the implementation of nationwide fall prevention initiatives have usually tackled this complex problem in isolated components. For example, studies have assessed the effectiveness of screening tools [18, 19] and programmes [20], evaluated the determinants of implementation [21], and investigated the cost-effectiveness of programmes [22], etc. While these studies are critically important for advancing the tools to prevent falls, there is a lack of information about the impact of strategies through a consolidated view of the healthcare system for falls prevention among community-dwelling older adults. Notably, Kwon et al developed a discrete event simulation model to assess the health economic performance of the UK guideline-recommended falls prevention strategy [23]. The model simulated individuals' progression through proactive, reactive and self-referred pathways, incorporating fall types, exit points, and both health and non-health outcomes [23]. While it did consider dynamics, it focused on the dynamic complexity between falls and frailty, and remained grounded on an individual-level framework. As such, the model was not designed to capture system-level feedback loops between demand and healthcare capacity [24], nor did it endogenously represent resource constraints, time delays and emergent system bottlenecks when interventions are scaled [25].

Therefore, in this present study, we hypothesized that combining falls prevention strategies targeting system leverage points reduction the number of older adult fallers by 2040 compared to the business-as-usual scenario. To do so, a systems dynamics modelling approach to examine the potential medium to long-term impacts of different strategies, by modelling the interactions between population ageing, intervention uptake and service capacity over time. This study aims to: (a) understand the current workflows of falls among older adults in Singapore, (b) identify system bottlenecks that limited the effectiveness of the scenarios , and (c) estimate the health and service-level impacts of various nationwide prevention strategies. Ultimately, this study seeks to inform how Singapore can systematically scale community-based falls prevention to meaningfully reduce the national burden of falls and support healthy ageing at a population level.

Methods

A dynamic model was built to generate insight and understand the impact of implementing a national falls prevention strategy in Singapore. Systems dynamics modelling can capture system-level feedback relationships and accumulation processes [25], to examine how the population interacts with the healthcare system in different situations. SDM has been used to generate insight or forecast scenarios for healthcare planning and design. It is underpinned by a well-established mathematical theory of nonlinear dynamics [26] and has been applied in various public health and healthcare policy studies. A core feature of this approach is its ability to account for the dynamic complexity of healthcare challenges, where multiple interdependent factors influence health outcomes in nonlinear ways [26]. By representing the structural relationships between key components within the health system, SDM enables the identification of bottlenecks and assessment of intervention effectiveness to inform strategic policy decisions.

A deterministic SD model was built using Vensim DSS v10.1.3 [27] to reflect the business-as-usual (BAU) scenario of falls among older adults in the Singapore resident population, generate insights through policy scenario analysis for falls reduction, and identify system bottlenecks. A 30-year model was built, simulating yearly cycles from years 2010 to 2040.

Model Conceptualisation

We have previously developed a conceptual model illustrating the supply and demand factors influencing the implementation of falls prevention programmes in Singapore [15]. This conceptual model, in the form of a CLD, was developed with a diverse group of stakeholders pivotal to implementing such programmes in Singapore. This group of stakeholders ranged from healthcare professionals, community providers, researchers and policymakers. Stakeholders also hypothesised potential strategies that could enhance the effectiveness of implementation. The conceptual model served as a "boundary object", a tool that enables cross-collaborations and mutual understanding across different organisational structures and disciplines [28, 29], to develop the quantitative SD simulation model.

Subsystems were first identified based on the conceptual model, which included: population dynamics, the natural history of falls, identification of risk, demand factors for screening and programme admissions, capacity factors for screening and programme admissions, and the effect of word-of-mouth in promoting the uptake of services. These subsystems were then consolidated into four main sub-models: 1. Natural History of Falls, 2. Dynamics of Screening, 3. Dynamics of Programme Admission, and 4. Growth by Word of Mouth. The model structure was then developed by identifying the stocks and flows through an iterative process that involved referring to the finalised CLD, conducting literature reviews, and stakeholder engagements.

Model Overview

1. *Natural History of Falls Sub-Model*

Model entry point begins at the natural history sub-model (Figure 1, 1. Natural History of Falls). This sub-model consists of a dynamic population model with an ageing chain simulating demographic changes over time. A similar structure had been used in previous studies [30, 31]. The Singapore resident population across all ages have been modelled. Those who were age 59 and below were accounted for in the stock "Population age below 60 years old". As our population of interest were older adults above 60 years old, the stocks following that were defined to allow for the accumulation of people 60 years old and above.

For those 60 years old and above, they begin at low risk for falls and can transition to being at high risk. A small proportion of those can also transition back to being at low risk for falls without active public health intervention. The transitions between low and high risk, and vice-versa, are determined by the transition rates for falls risk.

For those who were at high risk of falls, and demand for screening services, can be screened at public hospitals or in the community. Screening rates are determined by the existing demand and supply for screening services, which will be explained further in the *Dynamics of Screening* sub-model.

A proportion of those who have been identified as high risk for falls may uptake falls prevention services. The rate of admission is the function between the high-risk population demanding programmes and the uptake fraction, which determines the total population in programmes. At base case, the programmes being simulated are group-based exercise programmes that are typically recommended to older adults to maintain their general physical fitness. A proportion of this population will complete the programme, and they are accounted for in the "Population completed programmes" stock. For those who drop out of programmes, this population moves back to the previous stock and accumulates at "High risk population screened". In addition, for those who have completed the exercise programmes but fail to adhere to the lifestyle changes over a five-year period can regress back to being at high risk again, in which case, this cohort would have to be screened again to be admitted into another programme. These feedback pathways ensure that the model represents how people flow in and out of group-based exercise programmes realistically.

To ensure that the population model is dynamic, a consistent ageing process across the time horizon has been accounted for in the model. In addition, the population is also described with a three-dimensional vector to characterise the population's age (from 0 – 100 years and older), gender (male and female) and falls risk (high and low). Modelling details of the population dynamics can be found in the supplementary text.

2. *Dynamics of Screening*

The stock "high risk population screened" is determined by the rate of high risk screened, which is a product of the screening rate, and the fraction of those at high risk who demand for screening services (Figure 1, 2. Dynamics of Screening). The screening rate is influenced by the existing resources for screening in both community care and in public hospitals. Similarly, those who are at low risk for falls may also demand screening services, which generates a competition for screening services between those who are at low risk and high risk for falls.

The available resources for screening in community care and hospitals in Singapore was calculated by the number of geriatricians in public hospitals and the number of community health nurses in community health posts. The rate of growth was calibrated from existing data obtained from the Singapore Medical Council [32]. Further details can be found in the supplementary text.

3. *Dynamics of Programme Admission*

The population in programmes is determined by the admission rate, which is a product of the rate of conducting programmes and the fraction of those who have been screened and are demanding for programmes (Figure 1, 3. Dynamics of Programme Admission). The rate of conducting programmes is influenced by the existing resources for programmes, which are defined by the available number of care workers in Active Ageing Centres (AACs) in Singapore. This represents the primary site where community-based falls prevention programmes would be implemented. In addition, capacity is further broken down to the number of programmes each care worker can attend to in a year, the number of available programmes and the duration of each programme.

4. Growth by Word of Mouth

The rate of uptake for programmes determines the number of high risk population demanding for programmes. This rate of uptake is a function of the baseline uptake, obtained from reports from the Ministry of Health, and the effect of Word of Mouth (WOM). The effect of WOM is a positive feedback loop, where the greater number of people completing programmes and greater proportion satisfied with programmes promotes a greater WOM effect. The effect of WOM then promotes uptake for programmes, which can encourage more people getting admitted and completing programmes. A simplified WOM molecule **[33]** has been developed for this model due to the lack of studies on the impact of WOM in Singapore. This has been calibrated to the overall uptake observed by older adults across studies in Asia and Singapore **[34, 35]**.

Modelling details and governing equations for the model are provided in the Supplementary Text and Supplementary Table 1.

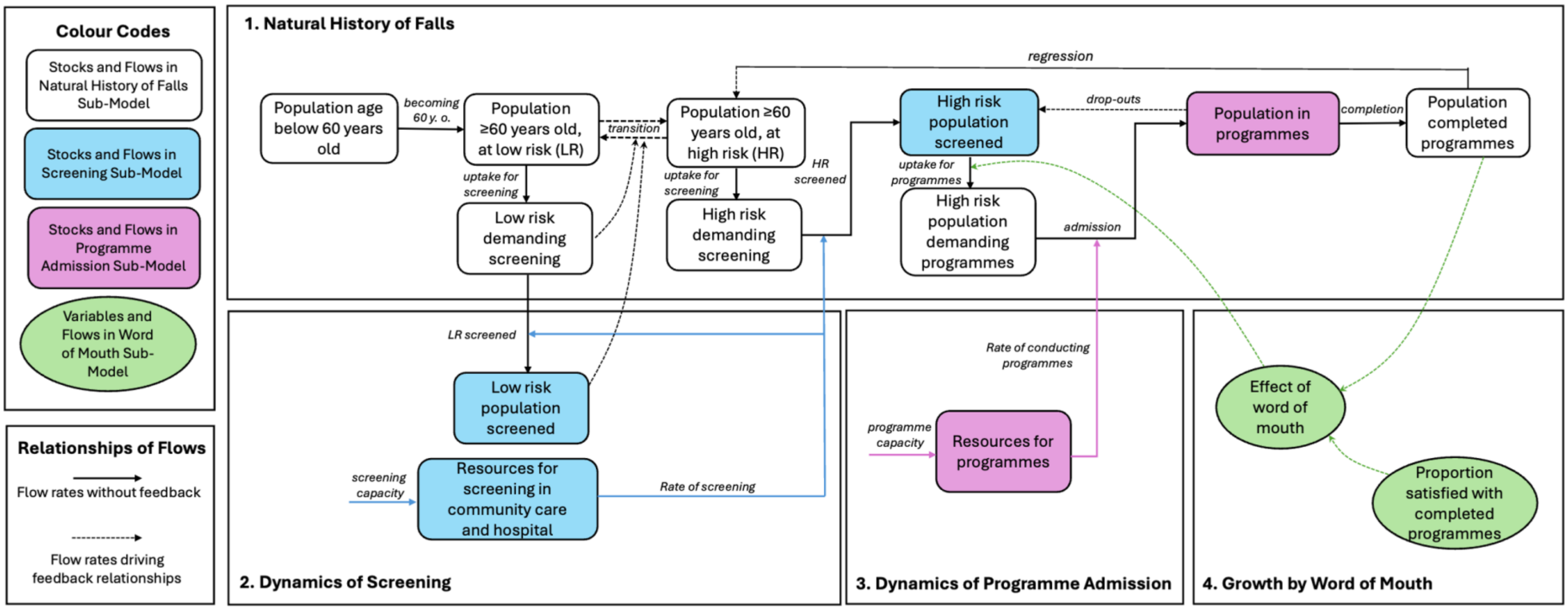

Figure 1 Model representation diagram.

Model parameterisation and validation

Model parameterisation sought to contextualise the model based on Singapore's resident population and healthcare eco-system. The SD model incorporates data from multiple sources, including data from the Singapore Department of Statistics, the WHO Global Burden of Disease database, and published literature prioritised in the following order for use: (i) systematic reviews and meta-analysis, (ii) studies from Singapore, (iii) studies from other Asian settings, (iv) any other peer-reviewed studies. Data from systematic reviews and meta-analyses were prioritised as the pooled data provide greater certainty, enhancing the robustness of the simulation model. Preference was also given to sources that included studies from Singapore and/or Asia. For parameters that lack available information, experts from Singapore were engaged to estimate these numbers. These experts were geriatricians and healthcare professionals who were championing falls prevention in Singapore. Table 1 summarises the key parameters, estimated value and sources.

Table 1 Key parameters, estimate value and data sources

Key Parameters	Estimated Value	Data Sources
Natural History of Falls Sub-Model		
Initial Singapore resident population (2010)	3,771,721 people	Singapore Department of Statistics [36]
Age-specific fertility rates	Annual national data	Singapore Department of Statistics [36]
Age-specific death rates	Annual national data	Singapore Department of Statistics [36]
Annual transition rates between low and high falls risk	0.0690052 dmnl/year	Fitted based on age-gender-specific falls rates obtained from WHO Global Burden of Disease Database [37]
Annual transition rates between high and low falls risk	0.011432 dmnl/year	Fitted based on age-gender-specific falls rates obtained from WHO Global Burden of Disease Database [37]
Age-gender-specific fall rates	Annual national data	WHO Global Burden of Disease Database [37]
Efficacy of falls prevention	OR = 0.22 (95% CI: 0.07 – 0.67)	Systematic analysis and meta-reviews on efficacy of falls prevention programs [38]
Programme drop-out rate	Interpolated: 0% at time 0, 25% at 3 months, 50% at 6 months, 65% at 1 year)	Expert estimation (Lookup table across 1 year)

Annual rate of regression	Interpolated: 0% at time 0, 25% at 6 months, 50% at 9 months, 75% at 1 year and 100% by 1.5 years	Expert estimation (Lookup table interpolated within a year for trends a typical 2-year trend. This one done as a cycle length = 1)
	Dynamics of Screening	
Initial number of available geriatricians in Singapore	47 people	Singapore Medical Council [32]
Total number of available geriatricians in Singapore (including old and new geriatricians)	Annual	Singapore Medical Council [32]
Total number of available community health nurses posts in Singapore (including old and new nurses)	Annual	Information from Regional Health Clusters [39-41]
Number of patients screened each day in hospital and in community health posts	4 people from Hospital 7 people from Community	Expert estimation
	Dynamics of Programme Admission	
Number of Active Ageing Centres (AACs) for proramme s as a proxy for number of care workers	264 centres	Ministry of Finance Singapore [42]
Length of programs (months)	¼ year	[43]
Trainer to Provider ratios	1:20 trainer to participant ratio in Group-Based Programmes 1:8 trainer to participant ratio in Specialized Programmes	Expert elicitation
Programme uptake	40-50%	[34, 35]
	Growth by WOM	
Programme satisfaction after completion	85%	[44]

Model validation was conducted with structure, structure-oriented behaviour and behaviour validation [45]. For structure validation, the face validity of the structure of the model, outputs and operational knowledge of the model were verified with experts qualitatively. These experts consisted of geriatricians and researchers familiar with the context of falls prevention and implementing falls prevention in Singapore's health system. Structure-oriented behaviour validation was also conducted using extreme-value testing by verifying the flows of the model by calculating outputs in different conditions at each step of model development. Lastly, behavioural validation was conducted by ensuring the model was consistent with current data and trends. This was also conducted by providing this evidence to experts, who sought to clarify model trends and structure to ensure that model finds aligned closely with real-world evidence.

Outcomes of Interest

The outcomes assessed in this study include health and capacity outcomes. The primary outcome is the (i) total number of older adult fallers in Singapore. The capacity outcomes refer to the available capacity of screening and falls prevention services. These are (ii) the total number of individuals that can be screened in out-patient hospital settings, (iii) the total number of individuals that can be screened in community health posts, and (iv) the total number of patients who can be treated within falls prevention programmes in a year.

The model also provides other estimations of parameters including the number of people at risk, prevalence of fallers, and the number of providers and care workers in the community.

Policy Scenarios

Besides the business-as-usual case, the policy scenarios (detailed in Table 2) to be simulated are as follows:

- Increasing participant uptake of services
- Increasing screening capacity for falls risk
- Introducing a primary screener to identify potentially high-risk individuals with increased screening capacity
- Implementing high-quality falls prevention programmes
- A combination of scenarios increasing participant uptake, increasing screening capacity and implementing high-quality falls prevention programmes
- A combination of scenarios increasing participant uptake, introducing a primary screener with increased screening capacity, and implementing high-quality falls prevention programmes

Table 2 Policy Scenarios.

Scenarios	**Details**
Business-as-usual (BAU)	The BAU scenario assumes no changes to key variables to the current landscape of falls prevention from 2020 to 2040.

	In the current state of falls prevention, screening and falls prevention services are conducted unsystematically. Screening and assessments are not done specific for falls risks, and community-based services for falls prevention are mainly group-based exercise programmes (and not prescribed exercises specific for falls prevention). These group-based exercise programmes do, however, focus on strength building and some balance training.
Increasing Patient Uptake for Current Services (Screening & Programmes)	In this scenario, the following variables were increased by 50% from Year 2026 to Year 2036 in a gradual 10-year implementation: • Visits to outpatient and community services. • Uptake for screening services. • Uptake for programs.
Increasing Capacity for Screening	In this scenario, the following variables were increased by 50% from Year 2026 to Year 2036 in a gradual 10-year implementation: • Increasing availability of providers for screening in hospitals and community-setting. • Encouraging retention among hospital and community workers.
Increasing Capacity for Screening and Introducing a Primary screener	This scenario explores introducing a primary screener at low/no cost along with increased screening capacity. This primary screener should help to identify older adults who may be at higher risk of falls, enabling those who are at high risk of falls to receive the necessary services. This can be implemented at the triaging stage or as a self-checklist. After the primary screener identifies those who may be at high risk for falls, these people then undergo a secondary screener (current screening methods) for better identification of risk and risk factors. The primary screener is hypothesised to better prioritise those in need, to relieve the burden of the healthcare system from upstream. The following variables were increased by 50% from Year 2026 to Year 2036 in a gradual 10-year implementation: • Increasing availability of providers for screening in hospitals and community-setting.

<table>
<tr><td></td><td>• Encouraging retention among hospital and community workers.</td></tr>
<tr><td>Implementing High Quality Falls Prevention Programmes</td><td>This scenario explores:
• Replacing group-based exercise programmes with multi-component falls prevention programmes, hence changing the efficacy of programmes in reducing falls.
• Changing the trainer to participant ratio changes to 1:8 from 1:20.

The following variables were increased by 50% from Year 2026 to Year 2036 in a gradual 10-year implementation:
• Increasing availability of providers for screening in hospitals and community-setting.
• Encouraging retention among hospital and community workers.
• Increased capacity of falls prevention providers.
• Encouraging retention of care workers.</td></tr>
<tr><td>Combination Policy</td><td>This scenario is a combination of scenarios of increasing uptake, increasing screening capacity and implementing high-quality falls prevention programmes. Three intensities were modelled – Limited, Moderate and Ideal Cases, the Limited and Ideal cases are presented in the supplementary sections. The Moderate case is described as follows.

The following variables relating to uptake of services were increased by 50% in a gradual 10-year implementation:
• Visits to outpatient and community services.
• Uptake for screening services.
• Uptake for programs.

The following variables relating to increasing capacity for screening were increased by 70% in a gradual 10-year implementation:
• Increasing availability of providers for screening in hospitals and community-setting.
• Encouraging retention among hospital and community workers.

The following variables for implementing falls prevention programmes were increased by 70% from Year 2026 to Year 2036 in a gradual 10-year implementation:</td></tr>
</table>

	• Increasing availability of providers for screening in hospitals and community-setting. • Encouraging retention among hospital and community workers. • Increased capacity of falls prevention providers. • Encouraging retention of care workers. Group-based exercise programmes were replaced with multi-component falls prevention programmes and changing the trainer to participant ratio from 1:20 to 1:8 was modelled as well.
Combination Policy with Primary Screener	This scenario is a combination of scenarios of increasing uptake, introducing a primary screener while increasing screening capacity and implementing high-quality falls prevention programmes. Three intensities were modelled – Limited, Moderate and Ideal Cases, the Limited and Ideal cases are presented in the supplementary sections. The Moderate case is described as follows. The following variables relating to uptake of services were increased by 50% in a gradual 10-year implementation: • Visits to outpatient and community services. • Uptake for screening services. • Uptake for programs. The following variables relating to increasing capacity for screening were increased by 70% in a gradual 10-year implementation: • Increasing availability of providers for screening in hospitals and community-setting. • Encouraging retention among hospital and community workers. Additional structure was provided in the model to segment the population prioritised by the primary screener, enabling those who are at potentially high risk to receive secondary screener services. The following variables for implementing falls prevention programmes were increased by 70% from Year 2026 to Year 2036 in a gradual 10-year implementation: • Increasing availability of providers for screening in hospitals and community-setting.

	• Encouraging retention among hospital and community workers. • Increased capacity of falls prevention providers. • Encouraging retention of care workers. Group-based exercise programmes were replaced with multi-component falls prevention programmes and changing the trainer to participant ratio from 1:20 to 1:8 was modelled as well.

Sensitivity Analysis

Sensitivity analysis was performed to assess uncertainties and evaluate the robustness of the findings.

To understand the impact of scenarios at a more granular level, increments to the variables for all scenarios were modelled at: 40%, 50%, 70% and 100%. Increasing variable inputs by 50% was presented in the findings while all other increments were presented in the supplementary text. In addition, all univariate and multivariate sensitivity analysis were conducted for all these additional as well.

Univariate sensitivity analysis was conducted with a +/-10% variation in parameter values to determine which parameters have the greatest impact on key outcomes of interest related to progression of falls risk, number of fallers, demand and supply of screening, and demand and supply of program admission. This is done so by holding all other parameter values constant across 2800 simulations and conducting one-way sensitivity analysis of all parameters on the outcomes of interest. Parameters which demonstrated the highest variation from the mean, and were modifiable parameters for future intervention, were then selected for multivariate sensitivity analysis. To estimate the uncertainty and variability in outcomes of interest, Monte Carlo multivariate sensitivity analysis was conducted for all scenarios to determine the mean and 95% confidence ranges (95% CR) across 1000 simulations.

Results

Business-as-Usual Scenario

Comparing to the base-case at 2026, the number of older adults in the business-as-usual (BAU) scenario will grow from 271,648 (266,976 – 276,321) to 370,394 (95% CR: 364,155 – 376,634) (Table 3). The total prevalence of falls will grow from 22.6% (95% CR: 21.2% - 21.9%) to 24.4% (95% CR: 24.0% - 24.8%) at 2040 (Table 4).

Findings from the simulation model project that a total of 186,588 older adults may be screened for fall risk by 2040. This translates to 22,778 (95% CR: 22,200 – 23,357) and 163,810 (95% CR: 159,582 – 168,038) patients screened in the outpatient hospital and in community health posts, respectively. 71,944 (95% CR: 70,739 – 73,149) patients are expected to be enrolled into community-based exercise programmes based on existing programme capacities to reduce their falls risk.

The overwhelming demand for services and limited capacities by 2040 is illustrated in Figure 2. Up to 2033, the current supply of group-based exercise programmes is well-matched to the demand from older adults at risk and seeking services. However, beyond 2033, demand continues to rise while the rate of supply growth remains constant. Without interventions in the BAU scenario, modelling suggests that the gap between demand and supply will widen, potentially leading to more older adults falling and increasing the associated healthcare burden. Modelling results indicate a widening gap between available services and actual need as well.

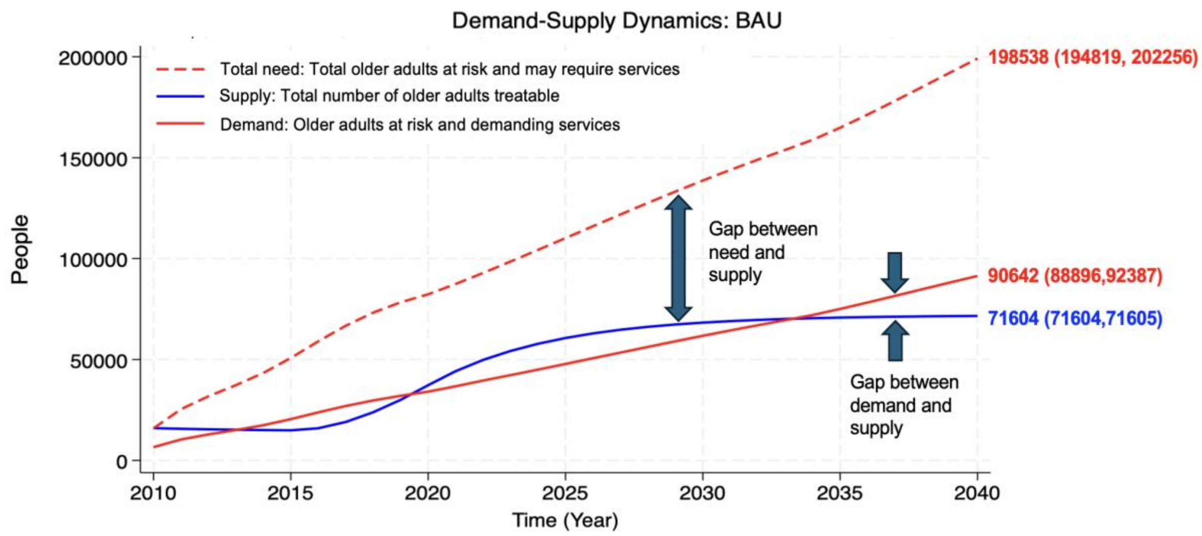

Figure 2 Demand and Supply Dynamics of Group-based Exercise Programs: BAU Scenario

Increasing uptake of services

In the scenario when increasing the population's uptake for services, this demonstrated limited change in the total number of older adults who fell compared to business as usual (BAU). The total number of older adult fallers is 379,311 (95% CR: 372,964 – 385,658), with the prevalence of 24.4% (95% CR: 24.0% - 24.9%) (Table 12). The total demand for falls prevention services increased by 34.2% (33.7% - 34.7%), when comparing to BAU scenario at 2040 (Supplementary Table 3).

Increasing Screening Capacity

With the increase in screening capacity, the total number of fallers begin to reduce in this scenario. The total number of older adult fallers at 2040 is 371,868 (95% CR: 365771 – 377,964), which is a -1.8% (95% CR: -1.7%, -1.8%) percentage reduction in total number of older adult fallers compared to BAU at 2040 (Table 3).

Introducing a Primary Screener and Increasing Screening Capacity

When introducing a primary screener alongside increases in screening capacity, the total number of older adult fallers at 2040 is 358,529 (95% CR: 352,557 – 364,501), which is a -1.5.3% (95% CR: -5.3%, -5.3%) reduction in total number of older adult fallers compared to BAU at 2040 (Table 12). This scenario shows a marked improvement compared to only increasing screening capacity, as the primary screener prioritises individuals potentially at high risk for falls for services. This allows for such individuals to receive care at a faster rate.

In addition, the capacity for screening in the hospital and community increased by 51% (50.5% - 51.1%) (Supplementary Table 4) and 37.9% (37.9% - 37.9%) (Supplementary Table 5).

Implementing High-Quality Falls Prevention Programs

In the scenario implementing high-quality falls prevention programmes only, by 2040, the total number of older adult fallers is 358,890 (95% CR: 352,689 – 365,091), a -5.2% (95% CR: -5.2%, -5.1%) percentage reduction in total number of older adult fallers compared to BAU at 2040 (Table 12).

By increasing capacity for falls prevention programmes by 50%, this will result in more older adults being treatable. As this scenario does not impact demand, the supply will exceed demand, and this gap will increase over time (Figure 3, with BAU supply and demand shown for reference in grey).

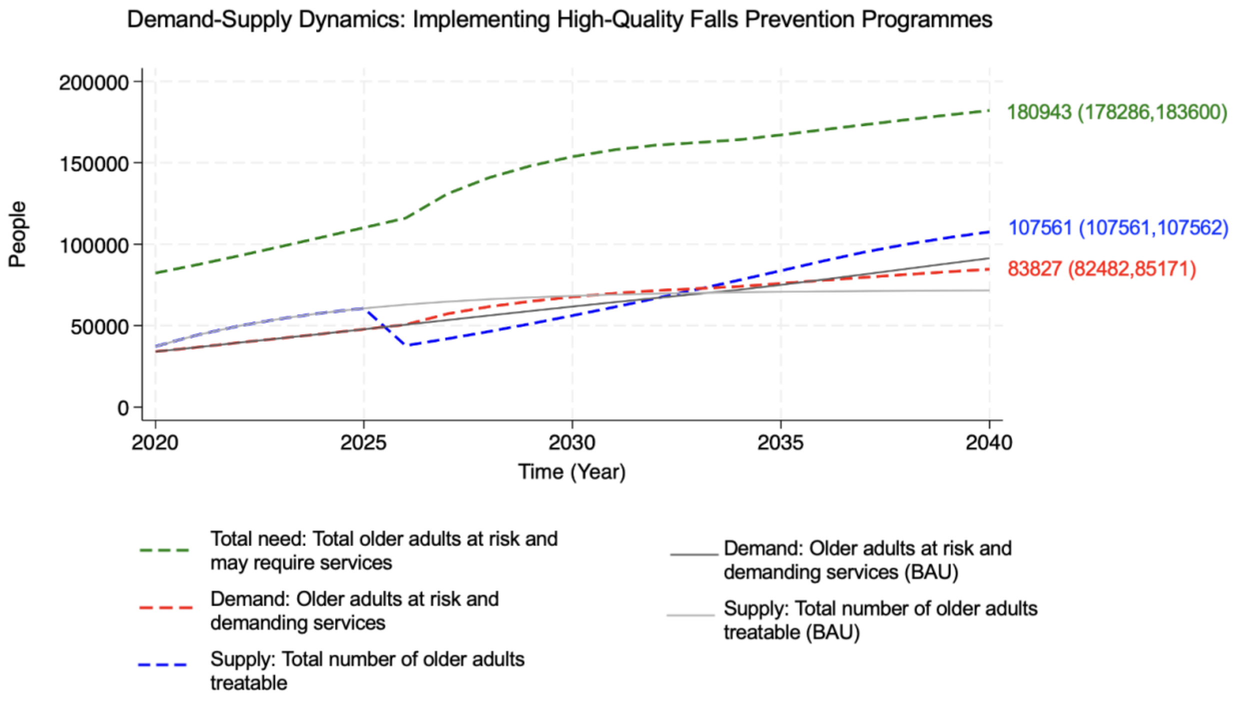

Figure 3 Demand and Supply Dynamics of Falls Prevention Programmes: Implementing High-Quality Falls Prevention Programmes Scenario

Combination: Increasing uptake for services, increasing screening capacity and implementing high-quality falls prevention programmes.

In this scenario, combining policies for promoting uptake, building capacity for screening and implementing falls prevention programmes, the total number of older adult fallers is 344,792 (95% CR: 338,789 – 350,795), and there was a -8.9% (95% CR: -9.0%, -8.8%) percentage reduction in total number of older adult fallers compared to BAU at 2040 (Table 3). The prevalence of fallers also decreases to 22.2% (21.8% - 22.6%) compared to the BAU scenario by 2040 (Table 4).

The gap between demand and supply for falls prevention programmes reconcile in the year 2035, about 10 years after gradual policy implementation (Figure 4).

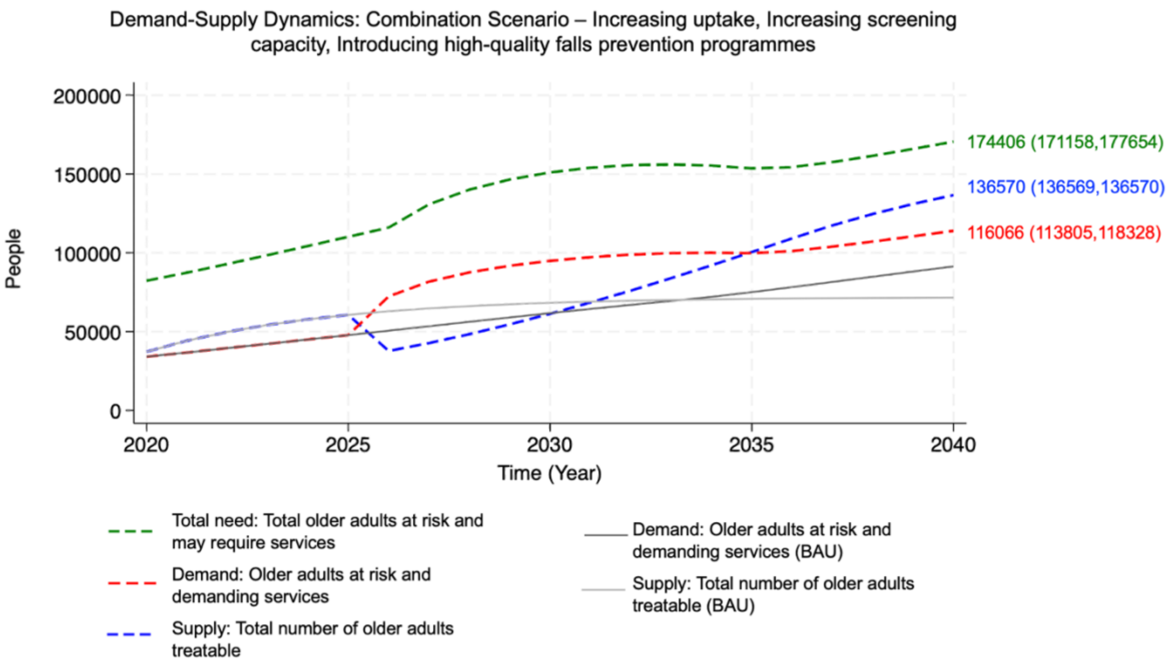

Figure 4 Demand and Supply Dynamics of Falls Prevention Programmes for Combination Scenario (Increasing uptake, increasing screening capacity and introducing high-quality falls prevention programmes).

Combination: Increasing uptake for services, introducing primary screener while increasing screening capacity and implementing high-quality falls prevention programmes.

Modelling results from this scenario demonstrate that the total number of older adult fallers is 330,418 (95% CR: 324,342 – 336,494), with a -12.7% (-12.9%, -12.6%) percentage reduction in total number of older adult fallers compared to BAU at 2040 (Table 3). The prevalence of fallers also decreases to 21.3% (20.9% - 21.7%) compared to BAU at 2040 (Table 4).

This scenario demonstrates a consistent increase in the demand for multi-component falls prevention programmes from older adults at high risk of falls across all cases (Figure 5). The demand and supply gap meets shortly after 2 years of intensive implementation. Due to aggressive increases in supply factors, along with structural changes by prioritising older adults who may be at higher risk of falls, this enables the total number of older adults treatable to increase at a faster rate compared to BAU. The increase in supply may exceed observable demand, however, they draw close to treating the total needs of the population.

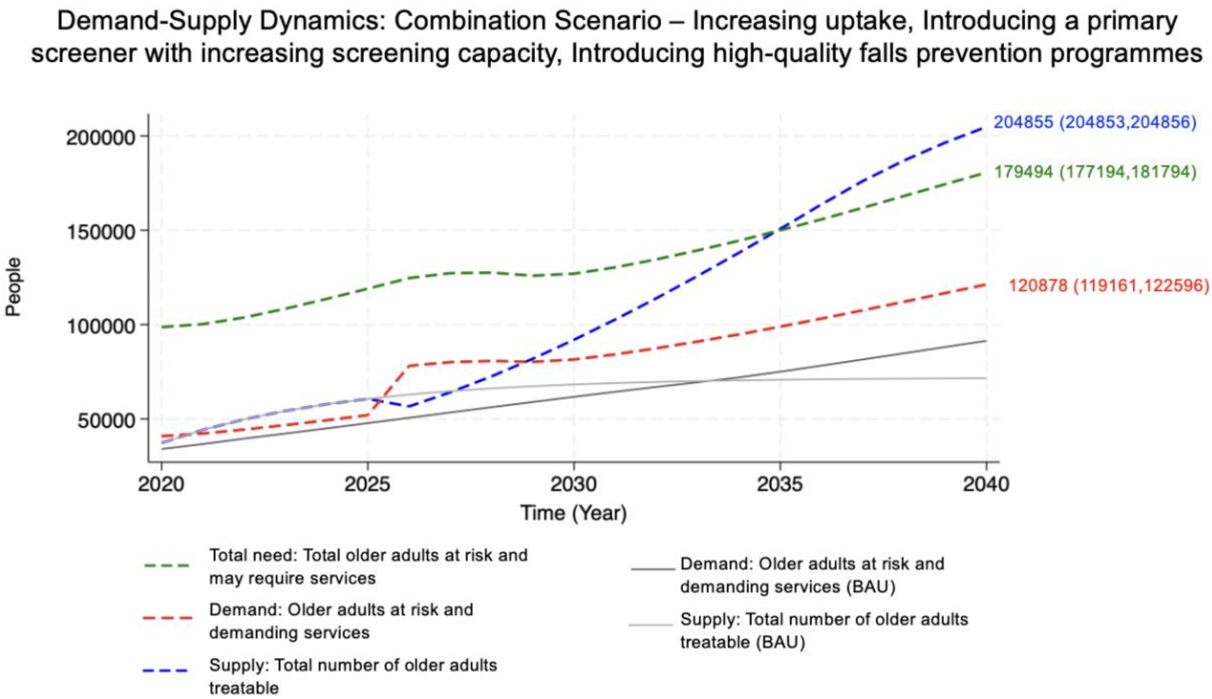

Figure 5 Demand and Supply Dynamics of Falls Prevention Programmes for Combination Scenario (Increasing uptake, introducing a primary screener with increasing screening capacity and introducing high-quality falls prevention programmes).

Table 3 Summary table of the total number of fallers and percentage change comparisons between business-as-usual (BAU) and policy scenarios at 2026 (policy implementation year), 2030 and 2040.

Scenarios	Total number of older adult fallers in 2026 n (95% CR)	Percentage difference in older adult fallers between scenario and BAU in 2026	Total number of older adult fallers in 2030 n (95% CR)	Percentage difference in older adult fallers between scenario and BAU in 2030	Total number of older adult fallers in 2040 n (95% CR)	Percentage difference in older adult fallers between scenario and BAU in 2040
Business-as-usual (BAU)	271,648 (266,976 – 276,321)	-	309,062 (303,734 – 314,389)	-	378,492 (372,175 –384,810)	-
Increasing Patient Uptake	271,648 (266,976 – 276,321)	0.0% (0.0%, 0.0%)	308,675 (303,328 – 314,022)	-0.1% (-0.1%, -0.1%)	379,311 (372,964 – 385,658)	0.2% (0.2%, 0.2%)
Increasing Capacity for Screening	271,648 (266,976 – 276,321)	0.0% (0.0%, 0.0%)	308,670 (303,356 – 313,985)	-0.1% (-0.1%, -0.1%)	371,868 (365771 – 377,964)	-1.8% (-1.7%, -1.8%)
Increasing Capacity for Screening with a Primary Screener	260,150 (255,750 – 264,549)	-4.2% (-4.2%, -4.3%)	297,565 (292,476 – 302654)	-3.7% (-3.7%, -3.7%)	358,529 (352,557 – 364,501)	-5.3% (-5.3%, -5.3%)
Implementing High Quality Falls Prevention Programmes	262,311 (257,677 – 266,944)	-3.4% (-3.5%, -3.4%)	298,484 (293,192 – 303,776)	-3.4% (-3.5%, -3.3%)	358,890 (352,689 – 365,091)	-5.2% (-5.2%, -5.1%)

Combination Policy	262,430 (257,794 – 267,066)	-3.4% (-3.4%, -3.3%)	296,659 (291,363 – 301,955)	-4.0% (-4.1%, -4.0%)	344,792 (338,789 – 350,795)	-8.9% (-9.0%, -8.8%)
Combination Policy with a Primary Screener	249,217 (244,853 – 253,582)	-8.3% (-8.3%, -8.2%)	280,736 (275,690 – 285,782)	-9.1% (-9.3%, -9.1%)	330,418 (324,342 – 336,494)	-12.7% (-12.9%, -12.6%)

Table 4 Prevalence of fallers at business-as-usual (BAU) and policy scenarios at 2026 (policy implementation year), 2030 and 2040.

Scenarios	Prevalence of older adult fallers at 2026	Prevalence of older adult fallers at 2030	Prevalence of older adult fallers at 2040
Business-as-usual (BAU)	21.6% (21.2%, 21.9%)	22.5% (22.1%, 22.8%)	24.4% (24.0% - 24.8%)
Increasing Patient Uptake	21.6% (21.2%, 21.9%)	22.4% (22.0%, 22.8%)	24.4% (24.0% - 24.9%)
Increasing Capacity for Screening	21.6% (21.2%, 21.9%)	22.4% (22.0%, 22.8%)	24.0% (23.6% - 24.4%)
Increasing Capacity for Screening with a Primary Screener	20.7% (20.3%, 21.0%)	21.6% (21.3%, 22.0%)	23.1% (22.7% - 23.5%)
Implementing High Quality Falls Prevention Programmes	20.8% (20.5%, 21.2%)	21.7% (21.3%, 22.1%)	23.1% (22.7% - 23.5%)
Combination Policy	20.8% (20.5%, 21.2%)	21.6% (21.2%, 21.9%)	22.2% (21.8% - 22.6%)
Combination Policy with a Primary Screener	19.8% (19.4%, 20.1%)	20.4% (20.0%, 20.8%)	21.3% (20.9% - 21.7%)

Sensitivity Analysis Results

The primary outcome, total number of fallers, was most sensitive to parameters related to screening and uptake of screening services. Uptake of services is behaviourally sensitive, while screening capacity was numerically sensitive. As such, combination scenarios prioritise more resources for building screening capacity compared to uptake of services. Tornado plots and multi-variate sensitivity analysis across all scenarios and increments were presented in the supplementary text in Supplementary Figures 1 and 2, and Supplementary Tables 2-4.

Discussion

A system dynamics simulation model was developed to examine the demand-supply dynamics of implementing falls prevention services for older adults in Singapore. Findings from the simulation model suggest that, in the absence of policy action, the number of older adult fallers will triple by 2040, with service demand far exceeding available capacity. While isolated strategies, such as enhancing uptake or expanding service capacity, resulted in marginal reductions in fallers, a more integrated, system-wide approach showed substantially greater impact. Among all the scenarios tested, the combination scenario involving enhanced uptake, expanded capacity, and targeted pre-screening achieved the largest reduction in fallers, while reconciling the gaps between demand and supply. This can only be achieved after accounting for system bottlenecks, identified via sensitivity analysis, and not simply through a blanket increment of all scenarios.

Although the reduction in prevalence of older adult fallers appears modest, declining from 24.4% (95% CR: 24.0% - 24.8%) under the BAU scenario to 21.3% (95% CR: 20.9% - 21.7%) in the combination scenario with primary screener, it is still impactful. This reflects the "Prevention Paradox," as described by Rose [46, 47], which explains that preventive health measures benefiting high-risk individuals may seem to deliver only a small overall impact at the population level. However, this small decrease in prevalence of the disease can represent a significant public health achievement. This is because it can be fuelled by a substantial absolute reduction in high-risk cases. In our context, this translates into an absolute reduction in the number of fallers (percentage change: -12.7% (95% CR: 12.9%, -12.6%)). It is important to also note that when studying the change in prevalence over time, the difference in prevalence from 2026, 2030 and 2040 is much greater over time when examining the BAU scenarios and combination scenarios.

Results from this modelling exercise demonstrate the value of adopting a system-wide perspective when designing policy interventions. Several key policy insights emerged by identifying structural bottlenecks and variables sensitive to outcomes. The following section elaborates on these insights and their implications for designing scalable nationwide falls prevention strategies in Singapore.

Policy Insight 1: Uptake and Capacity Expansion Alone has Diminishing Returns

This modelling exercise revealed limitations of isolated policy approaches to falls prevention, illustrating that merely increasing demand-side interventions, such as service uptake, or expanding supply for falls prevention programmes only, may yield diminishing returns.

Isolated increases in interest in group-based exercise programmes through public health campaigns and accessibility improvements would be expected to increase demand for such programmes by 27.3 – 52.3% compared to business-as-usual projections (Supplementary Table 2). However, this strategy did not result in a reduction in the total number of fallers. This is due to inaccessibility due to capacity constraints and the limited effectiveness of existing services.

This finding is consistent with a systematic review identifying determinants of fall prevention in residential care homes, where staffing issues, lack of human resources, and high rates of burnout among existing staff are key contributors to compromised care [48].

Similarly, isolated aggressive efforts to expand service availability yields diminishing returns, resulting in only -5.1% reduction in fallers. This is because, without parallel investments in screening and identification, expanded programmes struggle to recruit eligible participants at high risk of falls.

It is also important to note that implementing falls prevention programmes utilises a 1:8 trainer-to-participant ratio. This ratio, while optimal for clinical efficacy, service delivery, and maximising the quality of falls prevention programmes, may create challenges for scalability. Hence, rolling out falls prevention programmes across Singapore must be accompanied by increasing community manpower to run the programmes, to account for the smaller trainer-to-participant ratios.

Policy Insight 2: Targeted Screening to Optimise Limited Resources

System dynamics modelling revealed that combining targeted screening strategies while increasing screening capacity can optimise limited resources. Expanding screening capacity and introducing a low-cost primary screener for identifying potential older adults at risk of falls considerably reduces the number of fallers by 2040 compared to increasing screening capacity alone. In addition, sensitivity analysis demonstrated that variables related to screening capacity and services were crucial to determining the number of fallers (Supplementary Figures 1 and 2). This suggests the potential value of targeting evaluation and treatment to the "sweet spot" of population at high risk for falls, thereby maximising impact within resource constraints.

Like the CDC's STEADI Algorithm, risk screening can be implemented through a stepwise process. This can be done by using the Stay Independent Questionnaire or the Three Key Questions, followed by a more comprehensive risk factor and fall history assessment. These tools can be used as the primary screener, to indicate someone at potential high risk, before tailoring treatment based on careful evaluation of individuals' risk factors. This approach ensures that resource-intensive assessments are reserved for those most likely to benefit, preventing a bottleneck from developing for those who require a more comprehensive assessment. The American Geriatrics Society and British Geriatrics Society clinical practice guidelines also recommend screening all adults aged 65 and above annually but limiting comprehensive assessment to those with positive pre-screening results [49, 50].

Furthermore, the successful implementation of this targeted screening approach necessitates a thoughtful integration into existing healthcare workflows. In Singapore, primary care settings, such as polyclinics, general practitioners, and community health posts, offer an ideal environment for implementing falls risk screening due to their regular contact with most of the population [51, 52]. This has been implemented on a smaller scale as a quality improvement project utilising the CDC's STEADI toolkit in a primary care setting in the US [53]. Pre-screening using the Stay Independent Questionnaire was integrated into routine intake forms, which increased screening rates and leveraged existing patient touchpoints without creating additional appointments. Falls prevention screening should also be integrated throughout the healthcare system, which include primary care, hospitals, and community settings. Technologies can also be used to increase touchpoints as well as to ensure quality assessments at each touchpoint. For example, in a hospital in Singapore, artificial intelligence tools were used to monitor and predict bed exits of patients at risk of falls based on thermal heat mapping. This intervention was successful in predicting 100% of bed exits and reducing fall rates by 34% in geriatric wards, saving 67% of manpower hours as well [54]. The World Guidelines for Falls Prevention have also recommended opportunistic case findings through health records, where available [17]. In central China, a novel hospital-based falls risk management information system (FMRIS) was implemented to identify falls risk for all patients in a large academic medical centre, based on their health records. The FMRIS also includes a falls risk warning platform, a falls preventive strategy platform, and incident reporting and monitoring. This approach not only supported staff in identifying cases for intervention but also facilitated process control for nursing managers to ensure sustained falls prevention practices, from pre-screening to assessments and interventions [55].

Policy Insight 3: Synergistic Gains when Addressing Bottlenecks

Finally, findings from this work suggests that combinations of targeted policies while addressing key bottlenecks produced synergistic effects, exceeding the impact of the sum of individual interventions.

Isolated scenarios illustrate how inefficiencies arise when one part of the system advances ahead of others. This systems dynamics model enables policymakers to pre-empt potential issues by simulating outcomes and identifying bottlenecks in screening workflows, programme throughput, or workforce pipelines. By mapping feedback loops and capacity limits, decision-makers can anticipate where the system will strain and place “stopgaps” to prevent bottlenecks from arising. This is essential for policy decision-making to prevent the waste of resources by focusing on a specific area for implementation, as seen in the failure of other programmes, such as disease screening, which often led to limited follow-up [56] or over-testing and follow-up in individuals, resulting in patient burden and straining resources [57].

The combination scenarios represent a comprehensive approach to addressing this multifactorial, complex issue of implementing falls prevention in Singapore. As seen in the scenario combining of primary screener, expanding screening capacity, implementing high-quality falls prevention programmes, and increasing uptake, this demonstrated a notable 12.7% reduction in older adult fallers compared to business-as-usual. This improvement substantially outperformed the individual contributions of any single intervention approach. In addition, the total fraction of fallers compared to the entire population has the greatest difference when comparing with BAU as well.

Recommendations for Singapore and the Way Forward

The factors for successful implementation are congruent with those identified internationally [58] and in Singapore [15]. Beyond recognising determinants of success, this systems-level analysis supports actionable steps for policy planning. Policy priorities suggested here are (in order of priority): (i) introducing a primary screener to identify high-risk individuals, (ii) expanding screening capacity, (iii) scaling up high-quality programmes, and (iv) encouraging greater uptake.

Practically, changes can be introduced stepwise. First, there is a critical need to introduce primary screeners to identify individuals who are potentially at high risk and expand screening services across all touchpoints in the health system. A low-cost, objective, and accurate primary screener should be used to direct potentially high-risk individuals to more comprehensive screening. Examples of such primary screeners can include leveraging wearable technologies for quick and accurate screening [59-61], short questionnaires with high accuracy [62], or even digital self-assessments [63, 64]. A body should govern the selection of screeners (both primary and secondary screeners), such a Falls Prevention Work Group (FWG), where they have the authority to standardise all assessments based on their accuracy, feasibility for implementation and patient context [15, 17].

While screenings will take place in clinical settings, alternative to the delivery screening outside the health system should also be considered. Screening can be conducted in the community at community roadshows, AACs and community hubs. This should be done in collaboration with the regional health clusters, or with local GPs who can evaluate older adults at high falls risk. Digital tools for falls risk self-assessments should also be widely promoted [65, 66] by national agencies such as the Health Promotion Board. Regardless of the screening location, screening processes should be straightforward and efficient, with clear referral pathways clearly communicated to patients. Structured referral pathways and standardised workflows should be put in place in Singapore, as it is clear from model findings that falls prevention will require close coordination throughout the falls prevention continuum. Such referral systems are also being tested in other settings, such as in the UK and Ireland [67-69].

The second priority is expanding capacity for falls prevention programmes. Community and clinical workforce expansion and retention are top priorities. Current literature has repeatedly demonstrated that the barriers to implementing falls prevention programmes not only consist of managing patients/participants, but also operational constraints in delivering programmes [70, 71]. This is similar in Singapore, where there are limited resources to train and retain manpower [15]. A deliberate approach to developing health- and community-care resources is needed to attract and retain talent in career pathways for geriatric preventive care and active ageing.

Third, as capacity is being built for screening services and falls prevention programmes, there should be a mechanism to ensure screening with high accuracy and programmes that conform to standards required for high efficacy. As policymakers invest resources in recruiting and retaining talent, and building capacity for conducting community-based falls prevention, an FWG should provide guidelines for the core components that should be in programmes, and inform the tailoring of programmes based on falls risk [72, 73].

Finally, once a creditable infrastructure is in place, it is important to encourage greater uptake. In this regard, more work also needs to be done to measure older adults' preferences and their decision to participate, incorporate those data into models of those behaviors, and identify opportunities to make falls prevention activities desirable.

Implementing the optimised combination of strategies will require deliberate planning and governance with multiple specialties across different subsystems [74, 75]. This will require strong intersectoral coordination between stakeholders across different subsystems, such as health authorities, primary care providers, hospitals, and community providers. Establishing a structured referral pathway and integrated communication system will be key to ensuring strong coordination between these different groups and minimise the occurrences of constraints and bottlenecks. Future work in this area can utilise the WHO building blocks of health systems as a framework to study enhancing areas such as healthcare human resourcing, funding allocations and governance [71] as these building blocks also promotes developing policy .

Strengths and limitations

The SD modelling approach captures system-wide interactions within Singapore's falls prevention ecosystem, promoting an understanding of the mechanisms behind the implementation of community-based falls prevention programs. This can encourage *'in silico'* testing of various falls prevention strategies and identifying bottlenecks and/or unanticipated effects before large-scale implementation. A notable strength of this approach enables the continuous monitoring of system performance and using real-world evidence to refine modelling insights to make future decisions. Ongoing evaluations of model-based estimates using real-world evidence can also help policymakers understand shifts in dynamics or identify new bottlenecks, enabling them to adjust interventions proactively.

To the authors' knowledge, this community-based, population-level systems dynamics model for implementing falls prevention programs is the first of its kind. It is important to note that the model is conceptual in nature, hence is intended to be used primarily for insight generation rather than for precise numerical predictions.

For data inputs, the definition of "high-risk" is not yet standardised in global literature. As such, this may bring up uncertainties in modelling findings as it is difficult to compare and harmonise data inputs from different studies across the world. The effect size for "effectiveness of high-quality falls prevention programmes" used in the model was derived from a meta-analysis of different falls prevention programmes globally. By pooling data from different studies, the effect size for estimating the effectiveness of falls prevention programme can be more precise and less susceptible to variation or random chance. While this data may be more statistically sound, most falls prevention programmes in the research setting have yet to achieve such reduction in fallers due to the characteristics and design of the programmes. This may result in the effectiveness of falls prevention programmes, and subsequently reduction in total fallers, to overestimated. However, this estimate represents the highest level of effectiveness for falls prevention programmes and should set a policy standard for programmes to be implemented in Singapore.

The model is also unable to capture individual decision-making points (i.e., to participate or not to participate in screening/programs) as it simplifies uptake of programs in aggregate terms. Other types of dynamic modelling such as discrete events simulations and agent-based models may do a better job in doing so.

Lastly, the scope of this study aims to size the problem of falls among community-dwelling older adults and demonstrate the health burden of falls. Future iterations of the model will incorporate other important outcomes such as costs, quality of life or falls-related injuries. A full appraisal of the costs associated to fall-related injury will be conducted in a separate paper, and cost-effectiveness between the different scenarios will be assessed.

Conclusions

In conclusion, this study demonstrates the limited benefits of piecemeal approaches to tackling the problem of falls among older adults. It demonstrates the importance of a coordinated, system-wide strategy to sustainably reduce falls, by incorporating pre-screening, expanding screening and implementing high-quality falls prevention programmes in the community. Most importantly, implementation success depends on addressing system bottlenecks and coordinating different interventions across the healthcare setting.

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Supplementary Text

Model Overview

Natural History of Falls Sub-Model

Model entry point begins at the natural history sub-model. This contained a dynamic population model with an ageing chain that simulates demographic changes over time (Figure 1, 1. Natural History of Falls). A similar structure had been used in previous studies [30, 31]. Individuals were characterised by a three-dimensional vector to account for: age (from 0 – 100 years and older), gender (male and female) and falls risk (high and low).

To ensure a consistent ageing process across the time horizon of the model, the population aged 59 years and younger were accounted for in the state *"Population age 60 and below"* and ensured that individuals aged 60 years old transitioned to the older adult health state. In the state *"Population age 60 and below"*, population growth was accounted for through the national birth rate and net migration (estimated by calibration) and decreased by death and/or becoming age 60 years old. Birth rates were estimated using age-specific fertility rates obtained from the Singapore Department of Statistics, and life tables were used as inputs for age-specific death rates. Death rates were also accounted for in all other health states. At the end of each year of the model, the remaining population in each age cohort flows to the next cohort (i.e., Age 61 years old → Age 62 years old), except for the final age cohort (age 100 and older). Transitions across health states of high and low falls risk were calibrated by age- and gender-specific fall rates and total number of fallers from 2010 to 2021.

Dynamics of Screening

Screening rates to obtain the total number of older adults at high risk who have been screened *("High risk population screened"*) were derived by the competition between available screening capacity as well as total demand for screening.

Available screening capacity was calculated by summing the exogenous growth of the number of geriatricians in public hospitals and the number of community health nurses in community health posts. The rate of growth was calibrated from existing data obtained from the Singapore Medical Council [32] and policy guidelines for the expansion of community health posts. Screening for falls risks was conducted in both hospital and community settings, where providers were able to screen between 4 – 7 patients each working day (expert-provided estimates), depending on the setting. The total capacity for screening (i.e., the total number of patients that could be screened) was thus based on the product of the total number of providers and the available screening slots.

Total demand for screening is the sum of the demand among older adults who were at low risk and high risk for falls. Hence, there is also a competition between those at low and high risk for getting screened (Figure 1, Dynamics of Screening).

The total number of older adults who were screened was based on the competition between the total number of patients that could be screened, versus the total number of adults who demanded screening services i.e., *MIN(total number of patients that could be screened, total number of patients who demanded screening services)*. Demand for screening services was derived from the total demand from self-referred screening and opportunistic screening in primary care, outpatient clinics and community care settings. In the current system, no priority was given to any older adult; hence, people were screened on a first-come, first-served basis until the maximum capacity had been exhausted. Feedback relationships were also accounted for in this sub-model, where older adults can transition between the high and low risk health states. Transition rates between high and low risk health states were calibrated based on age- and gender-specific falls rates obtained from WHO Global Disease Burden data on fallers in Singapore.

Dynamics of Programme Admission

Similarly, the number of people who enrolled into programmes *("Population in programmes")* was determined by the competition between available capacity for conducting programmes and existing demand for services by older adults at high risk for falls (Figure 1, Dynamics of Program Admission), i.e., *MIN(number of older adults treatable per year, demand for services).* The available number of providers conducting programmes was calculated using the exogenous growth of the number of care workers in Active Ageing Centres (AACs) in Singapore, representing the primary site where community-based falls prevention programmes would be implemented. This was calibrated from existing data of AACs in Singapore [33] and expert elicitation. In the business-as-usual model, programmes were typically conducted in a 1:20 ratio, of one trainer to 20 participants. As such, the total capacity for services – i.e., the number of patients treatable per year through programmes – is a function of the number of care workers, the number of patients each care worker attends to, the number of available programmes in a year, and the duration of each program. Feedback relationships were also accounted for in the model, where the population who had dropped out of programmes return to the previous state (*"High-risk population screened")* and can undergo screening again to enroll in programmes. Similarly, for the population who completed programmes, a proportion of them may regress over time and transition back to being at high risk. It was assumed that the majority of older adults regress to being at high risk over a five-year period; this was estimated from expert judgement. These experts were geriatricians and healthcare professionals who were championing falls prevention in Singapore.

Growth by Word-of-Mouth

Finally, programme admission rates were also impacted by the effect of word-of-mouth (WOM) (Figure 1, Growth by Word-of-Mouth). A simplified WOM molecule [34] has been developed for this model due to the lack of studies on the impact of WOM in Singapore. This has been calibrated to the overall uptake observed by older adults across studies in Asia and Singapore [35, 36].

Governing equations for the model are provided in the Supplementary Table 1.

Supplementary Table 5 Key governing Equations for SD Model

Dynamic multi-state population model	Equations (1) and (2) show the aging process for the population under 60 years of age. Equation (1) applies to the aging process for newBorn, while that for age0 to age59 is represented by Eq. (2). (1) Population under 60[Gender, newborn] (t) = Population under 60[Gender, newborn] (t-dt) + (birth[Gender] + net migration[Gender, Newborn]- aging popUnder60[Gender, newborn] – deaths[Gender, Newborn]) * dt (2) Population under 60[Sex, under60allbutyoungest] (t) = Population under 60[Sex, under60allbutyoungest] (t – dt) + (aging[Gender,under60age59below]-aging[Gender,under60allbutyoungest]+net migration[Gender,under60allbutyoungest]-deaths [Gender,under60allbutyoungest]-becoming 60[Gender,under60allbutyoungest]) * dt where under60allbutyoungest refers to age0 to age59 where under60age59below refers to Newborn to age58 At the end of each simulation time, represented here as cohort length, the population in every cohort shifts to the subsequent age. This is done so by dividing the population cohort by the cohort length, which is a year. This process is represented by Eq. (3).

	(3) Population under 60[Gender, newborn] = Population under 60[Gender,under60age59below]/cohort length However, to ensure that age59 does not age in this stock (population under 60), we represent age59 as 0. We then created an outflow "becoming60" to move those age59 to age60 at the end of the year to the next stock, termed as "Population 60 years and older with low falls risk". (4) agingPopulation under 60[Gender, Age59] = 0
Screening rate and screening capacity	(1) Screeningrate[Gender,olderadults] = Population 60 years and older with high falls risk[Gender,olderadults]*proportion of high falls risk population screened and identified Where, the proportion of high falls risk population screened and identified is derived from the screening capacity model in both hospital and community. Hospital model (1) Total number of patients that can be assessed due to hospital capacity = Number of patients each provider can do assessments per year*Available providers for falls risk screening in hospitals (2) Total patients waiting for assessments at the hospital = older adults presented at SOC geriatric clinics in

	hospitals[RiskLevel]+Number of older adults referred by primary clinic to hospitals for conditions[RiskLevel] (3) Total Unique Patients Screened in hospitals = MIN(Total patients waiting for assessments at the hospital, Total number of patients that can be assessed due to available capacity) <u>Community model</u> (4) Patients who demand screening in the community = total population who may want to be screened in the community[RiskLevel]*proportion of patients who uptake screening[RiskLevel] (5) Total number of patients that can be screened due to available community capacity = Available providers for falls risk screening in the community*Number of patients each provider can screen for falls in the community per year (6) Total Unique Patients Screened in the community =MIN(Patients who demand screening in the community, total number of patients that can be screened due to available community capacity) Finally, (7) Proportion of high falls risk population screened and identified = (Total Unique Patients Screened in hospitals + Total Unique Patients Screened in the community) / Total population 60 years and older with high falls risk

Programme admissions	(1) Programme Admissions Per Year = Total unique patients actually treated with group-based exercise programmes each year/total older adults identified to be at high risk for falls and may require falls prevention services Where admission to group-based exercise programmes is based on programme capacity: (1) Number of unique patients treatable each year (capacity) = total number of class each care worker can run a year*number of unique patients each care worker can see in each class*Available trained care workers to conduct group-based exercise programmes (2) Total unique patients actually treated with group-based exercise programmes = MIN("Total number of unique patients treatable each year (capacity)", Unique older adults requiring and demanding for falls prevention in a year)

Supplementary Table 2 Summary Table of the total demand (total number of people who demand) for group-based exercise or falls prevention programmes, including change comparisons between policy and business-as-usual scenarios.

Outcome: Demand for Group-based Exercise or Falls Prevention Programmes (Summary Table)				
Scenarios	**2010 n (95% CR)**	**2040 n (95% CR)**	**Change from BAU at 2040 (per 1000 simulations) n (95% CR)**	**% change from BAU at 2040 n% (95% CR)**
Business as usual	6586 (6586,6586)	90642 (88896,92387)	0 (0,0)	0 (0,0)
Increasing uptake				
S1: 40% increase	6586 (6586,6586)	115346 (112783,117908)	24704 (23887,25521)	27.3 (26.9,27.6)
S1: 50% increase	6586 (6586,6586)	121634 (118868,124400)	30992 (29972,32013)	34.2 (33.7,34.7)
S1: 70% increase	6586 (6586,6586)	134374 (131203,137545)	43732 (42307,45158)	48.2 (47.6,48.9)
S1: 100% increase	6586 (6586,6586)	138008 (134707,141308)	47366 (45811,48921)	52.3 (51.5,53)
Increasing screening capacity				
S2: 40% increase	6586 (6586,6586)	102795 (100745,104845)	12153 (11849,12458)	13.4 (13.3,13.5)
S2: 50% increase	6586 (6586,6586)	105407 (103293,107520)	14765 (14397,15133)	16.3 (16.2,16.4)
S2: 70% increase	6586 (6586,6586)	110583 (108342,112824)	19941 (19446,20437)	22 (21.9,22.1)
S2: 100% increase	6586 (6586,6586)	118258 (115830,120686)	27616 (26934,28299)	30.5 (30.3,30.6)
Increasing screening capacity with Primary Screener				
S3: 40% increase	6586 (6586,6586)	118598 (116200,120996)	27956 (27304,28609)	30.8 (30.7,31)
S3: 50% increase	6586 (6586,6586)	121936 (119458,124415)	31294 (30562,32028)	34.5 (34.4,34.7)
S3: 70% increase	6586 (6586,6586)	128498 (125866,131129)	37856 (36970,38742)	41.8 (41.6,41.9)

S3: 100% increase	6586 (6586,6586)	137938 (135105,140771)	47296 (46209,48384)	52.2 (52,52.4)
Implementing community-based Falls Prevention Programmes				
S3: 40% increase	6586 (6586,6586)	86457 (84896,88018)	-4185 (-4000,-4369)	-4.6 (-4.5,-4.7)
S3: 50% increase	6586 (6586,6586)	83827 (82482,85171)	-6815 (-6414,-7216)	-7.5 (-7.2,-7.8)
S3: 70% increase	6586 (6586,6586)	82085 (80951,83219)	-8557 (-7945,-9168)	-9.4 (-8.9,-9.9)
S3: 100% increase	6586 (6586,6586)	81773 (80676,82870)	-8869 (-8220,-9517)	-9.8 (-9.2,-10.3)
Combination Scenario				
Limited Case	6586 (6586,6586)	122939 (120132,125747)	32297 (31236,33360)	35.6 (35.1,36.1)
Moderate Case	6586 (6586,6586)	116066 (113805,118328)	25424 (24909,25941)	28 (28,28.1)
Ideal Case	6586 (6586,6586)	124112 (121529,126696)	33470 (32633,34309)	36.9 (36.7,37.1)
Combination Scenario with Primary screener				
Limited Case	6586 (6586,6586)	113988 (112008,115968)	23346 (23112,23581)	25.8 (26,25.5)
Moderate Case	6586 (6586,6586)	120878 (119161,122596)	30236 (30265,30209)	33.4 (34,32.7)
Ideal Case	6586 (6586,6586)	128737 (126801,130674)	38095 (37905,38287)	42 (42.6,41.4)

Supplementary Table 3 Summary Table of the total capacity for screening in the hospital (i.e., the total number of people who can be screened from hospital outpatient settings), including change comparisons between policy and business-as-usual scenarios.

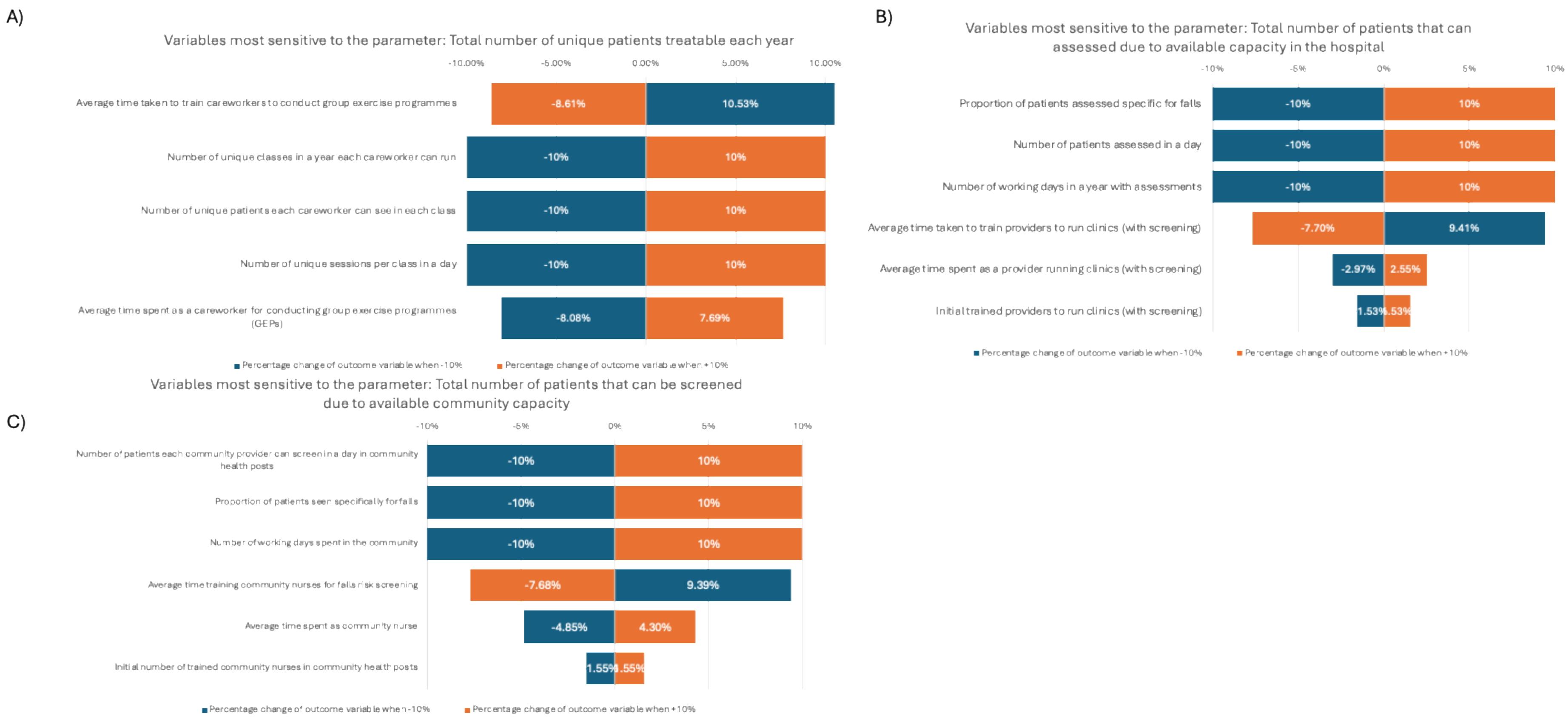
Outcome: Capacity for screening in the hospital, Total number of people who can be screened from the hospital (Summary Table)				
Scenarios	**2010 n (95% CR)**	**2040 n (95% CR)**	**Change from BAU at 2040 (per 1000 simulations) n (95% CR)**	**% change from BAU at 2040 n% (95% CR)**
Business as usual	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
Increasing uptake				
S1: 40% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S1: 50% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S1: 70% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S1: 100% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
Increasing screening capacity				
S2: 40% increase	2914 (2840,2988)	32305 (31483,33126)	9533 (9290,9775)	41.9 (41.9,41.9)
S2: 50% increase	2914 (2840,2988)	34392 (33517,35266)	11620 (11324,11915)	51 (51,51)
S2: 70% increase	2914 (2840,2988)	38565 (37584,39546)	15793 (15391,16195)	69.4 (69.4,69.4)
S2: 100% increase	2914 (2840,2988)	44825 (43685,45965)	22053 (21492,22614)	96.8 (96.8,96.8)
Increasing screening capacity + Primary screener				
S3: 40% increase	2914 (2840,2988)	32305 (31483,33126)	9533 (9290,9775)	41.9 (41.9,41.9)
S3: 50% increase	2914 (2840,2988)	34392 (33517,35266)	11620 (11324,11915)	51 (51,51)
S3: 70% increase	2914 (2840,2988)	38565 (37584,39546)	15793 (15391,16195)	69.4 (69.4,69.4)
S3: 100% increase	2914 (2840,2988)	44825 (43685,45965)	22053 (21492,22614)	96.8 (96.8,96.8)

Implementing community-based Falls Prevention Programmes				
S3: 40% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S3: 50% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S3: 70% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
S3: 100% increase	2914 (2840,2988)	22772 (22193,23351)	0 (0,0)	0 (0,0)
Combination Scenario				
Limited Case	2914 (2840,2988)	32305 (31483,33126)	9533 (9290,9775)	41.9 (41.9,41.9)
Moderate Case	2914 (2840,2988)	38565 (37584,39546)	15793 (15391,16195)	69.4 (69.4,69.4)
Ideal Case	2914 (2840,2988)	44825 (43685,45965)	22053 (21492,22614)	96.8 (96.8,96.8)
Combination Scenario with Primary screener				
Limited Case	2914 (2840,2988)	32305 (31483,33126)	9533 (9290,9775)	41.9 (41.9,41.9)
Moderate Case	2914 (2840,2988)	38565 (37584,39546)	15793 (15391,16195)	69.4 (69.4,69.4)
Ideal Case	2914 (2840,2988)	44825 (43685,45965)	22053 (21492,22614)	96.8 (96.8,96.8)

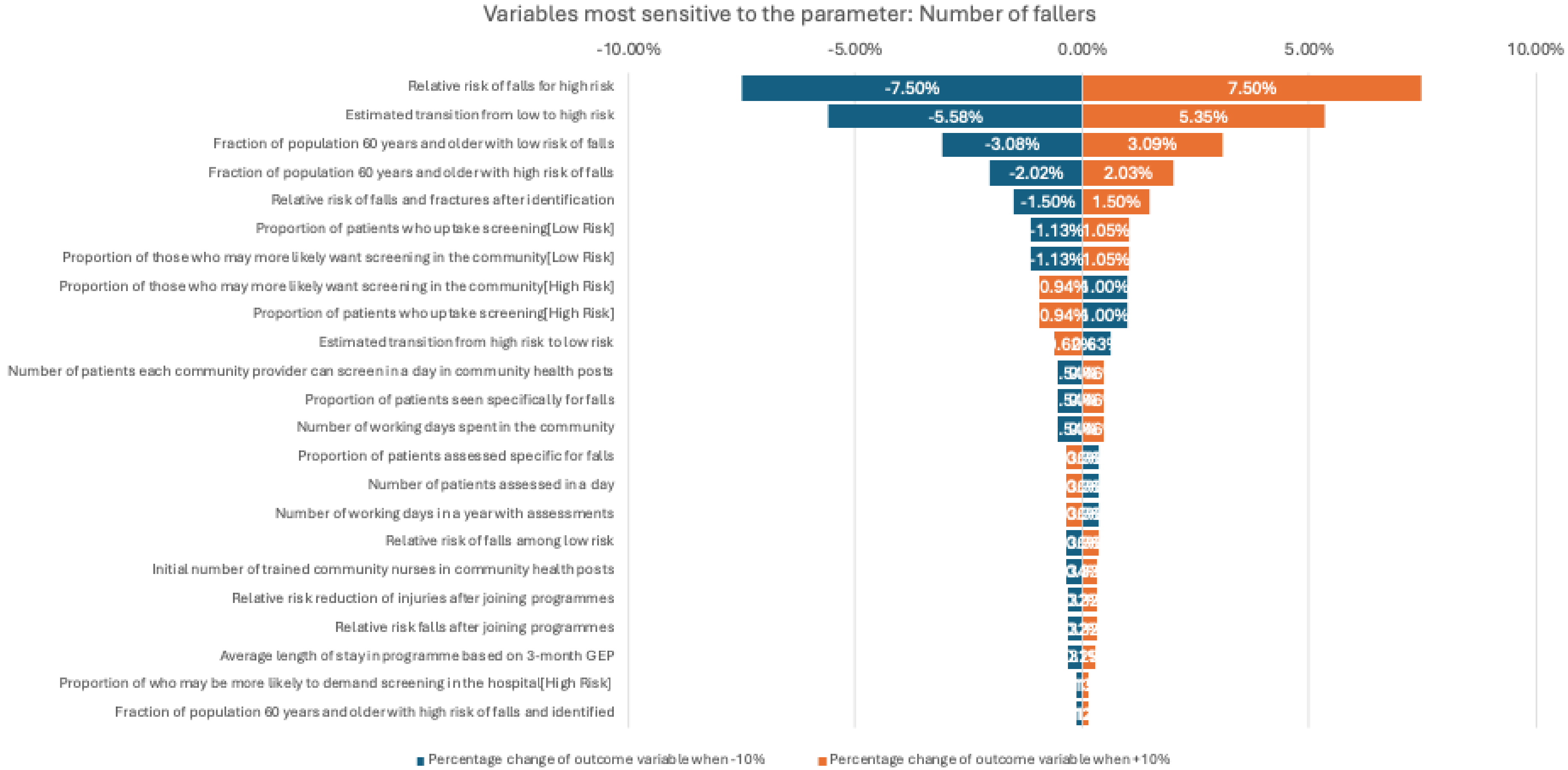
Supplementary Table 4 Summary Table of the total capacity for screening in the community (i.e., the total number of people who can be screened from community settings), including change comparisons between policy and business-as-usual scenarios.

Outcome: Capacity for screening in the community, Total number of people who can be screened from the community (Summary Table)				
Scenarios	**2010 n (95% CR)**	**2040 n (95% CR)**	**Change from BAU at 2040 (per 1000 simulations) n (95% CR)**	**% change from BAU at 2040 n% (95% CR)**
Business as usual	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
Increasing uptake				
S1: 40% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S1: 50% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S1: 70% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S1: 100% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
Increasing screening capacity				
S2: 40% increase	32107 (31279,32935)	209491 (204088,214894)	45580 (44405,46756)	27.8 (27.8,27.8)
S2: 50% increase	32107 (31279,32935)	225983 (220155,231811)	62072 (60472,63673)	37.9 (37.9,37.9)
S2: 70% increase	32107 (31279,32935)	258966 (252287,265645)	95055 (92604,97507)	58 (58,58)
S2: 100% increase	32107 (31279,32935)	308441 (300486,316396)	144530 (140803,148258)	88.2 (88.2,88.2)
Increasing screening capacity + Primary screener				
S3: 40% increase	32107 (31279,32935)	209491 (204088,214894)	45580 (44405,46756)	27.8 (27.8,27.8)
S3: 50% increase	32107 (31279,32935)	225983 (220155,231811)	62072 (60472,63673)	37.9 (37.9,37.9)
S3: 70% increase	32107 (31279,32935)	258966 (252287,265645)	95055 (92604,97507)	58 (58,58)

S3: 100% increase	32107 (31279,32935)	308441 (300486,316396)	144530 (140803,148258)	88.2 (88.2,88.2)
Implementing community-based Falls Prevention Programmes				
S3: 40% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S3: 50% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S3: 70% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
S3: 100% increase	32107 (31279,32935)	163911 (159683,168138)	0 (0,0)	0 (0,0)
Combination Scenario				
Limited Case	32107 (31279,32935)	209491 (204088,214894)	45580 (44405,46756)	27.8 (27.8,27.8)
Moderate Case	32107 (31279,32935)	258966 (252287,265645)	95055 (92604,97507)	58 (58,58)
Ideal Case	32107 (31279,32935)	308441 (300486,316396)	144530 (140803,148258)	88.2 (88.2,88.2)
Combination Scenario with Primary Screener				
Limited Case	32107 (31279,32935)	209491 (204088,214894)	45580 (44405,46756)	27.8 (27.8,27.8)
Moderate Case	32107 (31279,32935)	258966 (252287,265645)	95055 (92604,97507)	58 (58,58)
Ideal Case	32107 (31279,32935)	308441 (300486,316396)	144530 (140803,148258)	88.2 (88.2,88.2)



Supplementary Figure 6 Tornado Diagram of Univariate Sensitivity Analysis of variables most sensitive to (A) The total number of unique patients treatable each year for falls prevention programmes, (B) The total number of patients that can be screened in the hospital, (C) The total number of patients that can be screened in the community.



Supplementary Figure 7 Tornado diagram of Univariate Sensitivity Analysis of variables most sensitive to the total number of fallers.